be made by those in a position to obtain such material. The stem parts of both derris and cube should be investigated for their rotenone content as it is possible that these materials may contain sufficient rotenone to justify harvesting the whole plant rather than only the roots.

CONCLUSIONS

1. The rotenone content of 45 samples of derris root tested ranged from none to about 7 per cent, while that of 23 samples of cube root ranged from less than one to about 11 per cent. The average of the 31 samples of derris root analyzed by the carbon tetrachloride method was 2.5 per cent rotenone, while the average for the 22 samples of cube root analyzed by this method was 5.4 per cent rotenone. These averages should not be considered representative of derris and cube samples in general.
2. These results indicate the desirability of cube root as a source of rotenone. More extensive cultivation of this material is indicated. By selection of high rotenone strains of derris, the rotenone content of this plant could, no doubt, be improved.
3. A close correlation exists between the rotenone content and the total extractive materials of cube root. There is little or no correlation between these two values in the case of the derris root samples.
4. Fine derris roots have a slightly higher rotenone content than coarse roots.
5. Brazilian timbo root may afford an additional source of rotenone.

PALEONTOLOGY.—*Unique coloration of two Mississippian brachiopods.*

R. R. Rowley, Louisiana, Mo., and James S. Williams, U. S. Geol. Survey. (Communicated by John B. Reeside Jr.)

New and striking types of color patterns on fossils are always interesting and worthy of record, even though their origin may not be fully understood. Such a pattern has recently been discovered on two specimens of *Acanthospirina aciculifera* (Rowley) Schuchert and LeVene, and because it is apparently unique and may possibly be original, and because, even if not original, it may serve to focus critical attention on other color patterns that have been described as original, it seems advisable to call attention to it.

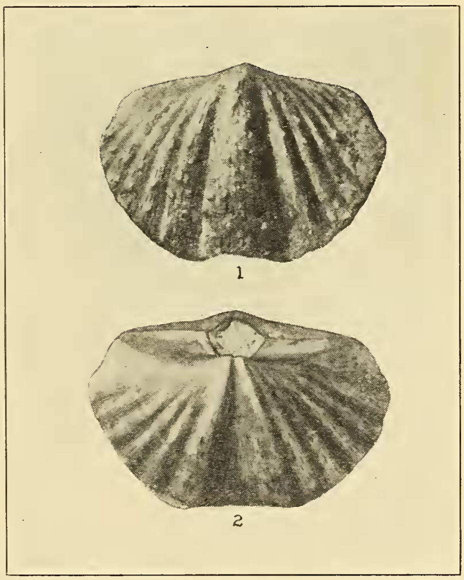
The color-marked specimens were collected by R. R. Rowley from the yellow-brown shale at the base of the Louisiana limestone (Lower

Mississippian), at the mouth of Buffalo Creek, one mile south of Louisiana, Missouri. Their preservation in shale permitted collection without mechanical injury, and thereby favored the retention of the finest markings.

The writers are very grateful to Dr. G. H. Girty and other members of the U. S. Geological Survey for helpful suggestions in the preparation of this notice. Thanks are also due Drs. Aug. F. Foerste and G. A. Cooper of the U. S. National Museum. Doctor Foerste examined the specimens and made suggestions regarding their interpretation and Doctor Cooper gave information about some of the brachiopods cited.

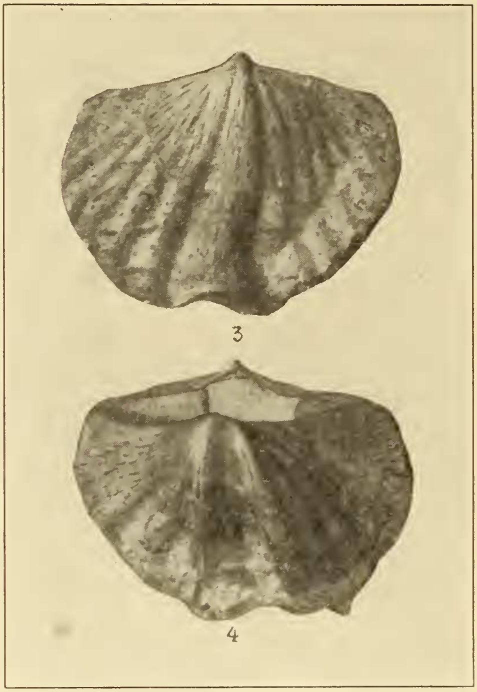
THE COLOR PATTERN

The striking appearance of the color pattern is caused by the bright red color of the markings and their distinctive arrangement.



Figs. 1 and 2. Two views of a specimen of *Acanthospirina aciculifera* (Rowley) Schuchert and LeVene (×8). Fig. 1—Brachial view showing tubercles and colored streaks. Fig. 2—Pedicle view, showing color pattern, which on the specimen is red. Few tubercles are preserved. (R. R. Rowley collection.)

Where most conspicuous the markings consist of bright red streaks and spots which are elongate in directions radial to the beaks and parallel to the plications. Though somewhat irregularly distributed, most of the markings conform to an arrangement in alternating radial rows. They are about as abundant on the plications as on the intervening furrows and occur both on the folds and in the sinuses. On one specimen the markings are not as abundant in the umbonal region as near the anterior margin, but on the other they are as common over the umbo as farther forward; on one they are more abundant on the



Figs. 3 and 4. Two views of a distorted specimen of *Acanthospirina aciculifera* (Rowley) Schuchert and LeVene (×8), showing color pattern. Note raised position of streaks near cardinal extremities on right side (to left in figure) of specimen shown in Fig. 4. (Univ. of Mo. collection, 5200).

left than on the right, but on the other shell they are about evenly divided between the two sides of the valves. The markings are shown in the photographs, Figures 1 to 4.

The streaks average about 0.16 mm. in length and about 0.02 mm. in width, but a few are longer than 0.16 mm. and others are only slightly longer than wide, being better termed spots than streaks. The markings are separated laterally by spaces that average about 0.1 mm. Examination under a magnification of 25 to 30 diameters, shows that most of the coloring material lies in short discontinuous grooves below the surface but some extends above it forming ridges.

Toward the anterior ends of a few of the grooves the coloring material rises and seems to continue beyond the grooves as short spines. Although most of the coloring material lies below the shell surface and therefore penetrates some of the inner shell layers, an examination under dark field illumination shows that none of it penetrates the innermost layer. Over most of the shell the color of the markings ranges from light brownish-red to dark red, the deeper shade being at the cardinal extremities of one specimen.

The red color of the pigment is probably due to the presence of iron in one or more compounds in the shell substance. Dr. C. S. Ross, of the United States Geological Survey, made a microscopic examination of the most abundant mineral in the red streaks and concluded that it was probably hematite, though the material was too fine grained to permit definite identification. He also found a few larger grains of limonite. Some of the coloring material appeared to him to have been recrystallized in place, and the small particles, he noted, were intermingled with particles of shelly material or imbedded as discrete particles in the shell substance. It was impossible to obtain enough coloring material for reliable and representative chemical analysis, but a few grains of it were tested in the Chemical Laboratory of the U. S. Geological Survey. These tests showed that the grains consisted of somewhat hydrated ferric oxide and that no organic matter was present.

Only four specimens of *Acanthospirina aciculifera* (Rowley) Schuchert and Le Vene are known to the writers. The two described here show the pattern in color, a third has the pattern excavated in the shell surface but not shown in color, and the fourth specimen has not been examined carefully for the pattern. A similar pattern was seen on young specimens of *Syringothyris hannibalensis* (Swallow) Hall and Clarke from the same locality and horizon but the writers have not seen it on mature forms. Other associated shells have incrustations of red material similar in color and composition to that forming the color pattern, but none of them have distinct patterns.

ORIGIN OF THE COLORATION

Rarely is it possible to establish definitely the origin of color markings on fossils. An examination of the literature shows that most of the markings known have nevertheless been described as original. Their origin appears to have been so interpreted because they were arranged in definite patterns which were observed on more than one individual. Although most of the markings so interpreted probably are original, their regular arrangement and occurrence on more than one individual is not, as will be shown later, of itself, sufficient evidence to definitely prove this conclusion. Satisfactory proof that the coloration on fossils is original is, however, possible. Such an origin can be proved where the chemical composition of the coloring material on the fossils corresponds to that of the pigments on recent shells, but, probably in most part because of changes during and after fossilization, the composition of color markings on most Paleozoic fossils differs from that of the markings on recent forms. Original coloration can be amply demonstrated where the color pattern is the same as a pattern on existing species of the same genus, but unfortunately this is also rare. Most other relations and characters that have been given as proof of original coloration are susceptible also of other interpretations, as a consideration of the Louisiana limestone specimens will show. It is not ordinarily so difficult to demonstrate the origin of secondary color markings, but few examples of them have been described, and the origin of even some of these examples is doubtful.

Like that of many of the markings described in the literature, the origin of the color markings on the Louisiana limestone specimens can not be definitely determined with the data available. Certain hypotheses are, however, favored by these data. A brief discussion of them will bring out interpretations and relations that have heretofore been passed over in studies of this kind and therefore seems desirable. Of these favored hypotheses, three appear to be the most plausible. In two of them, the first and third, the excavated pattern is assumed to have been caused by the coloring material or by material from which it was derived; in the other hypothesis the pattern is assumed to be the result of structural differences which probably did not originally involve differences in color or in shell composition. The three hypotheses are: (1) The coloration is original but has been partly or wholly changed in composition and partly obliterated, (2) the coloration is the result of infiltration of some mineral into openings in the shell, as into the punctae of a punctate shell or into the larger openings of hollow spines, and (3) the coloration is due to differentiation in shell composition (other than that caused by original color differences) which has been exaggerated and brought out by processes of fossilization.

So much is known of the composition of the brachiopod shell, that, unless the original substance of the shell has been replaced—which seems unlikely in the specimens in hand—the last hypothesis can be dismissed without detailed consideration. Differences in the composition of individual brachiopod shells, aside from those caused by differential and original coloration, largely consist of differences between shell layers. The pattern here described involves differences within shell layers and the arrangement of the materials causing them in a definite pattern. No arrangement of uncolored or uniformly colored materials in any way similar to the pattern has come to the writers' notice and none appears to have been described either from fossil or recent brachiopods. The probable absence of such an arrangement would, it seems, give ample justification for immediately dismissing the hypothesis that depends upon it.

Each of the other hypotheses provides explanations for all the observed characters and relations. The second hypothesis derives its strongest support from evidence furnished by the associated specimens, a source of evidence that has often been neglected. The commonness on associated specimens of stringers and incrustations of red iron-bearing material similar in appearance and composition to the material in the markings can possibly be explained as a fortuitous circumstance, but it shows that there was a plentiful supply of coloring material available for secondary introduction into a structural pattern. Uncolored structural patterns on associated individuals of the same species and on young individuals of *Syringothyris hannibalensis* (Swallow) Hall and Clarke may be interpreted as resulting from the removal of coloring material from original color patterns, but they may also be interpreted as structural patterns that were not originally related to coloration.

The depth of the excavations in which the markings on the color-marked individuals themselves are situated and the irregularity of the markings also favor the hypothesis that a structural pattern was infiltrated with coloring material after the death of the individuals that are now color-marked. The excavations are deeper than the irregularities that usually result from differential weathering of recent shells that have original color markings. The coloring material in five recent shells studied by the writers was in such minute quantities or was so nearly equal to the shelly material in resistance to solution that differential weathering did not affect the shell surface to any extent. This same relation appears to be true for most recent shells and unless the quantity of coloring material in fossil shells were greater than that contained in most recent shells known to the writers, it is doubtful that its removal alone would cause such deep depressions in the shell substance. Surface irregularities attributed (1, p. 81; 2, p. 212; 3, p. 281) to unequal weathering of pigmented and unpigmented parts of original color patterns on fossil cephalopods and on other fossils are, however, comparable to those caused by the excavations. The slight irregularity of the markings on the color-marked individuals of *Acanthospirina aciculifera* (Rowley) Schuchert and LeVene is not due to any irregularity in the pattern but instead is due to the absence of coloring material from the excavations. This absence might be explained by the assumption that the coloration was original and that unequal weathering of different parts of the shell and of its colored and uncolored parts removed the coloring material from some areas and left it in others; but the irregular distribution over the shell surface of excavations without coloring matter indicates that the absence of coloring matter from them was not the result of greater exposure of some parts of the shells to weathering and suggests that the explanation in terms of the second hypothesis that the irregularities are the result of unequal infiltration is more reasonable. If the coloring material did infiltrate previously formed openings in the shell there would be no reason to expect that it would infiltrate all openings alike or to the same degree.

A distinct obstacle to the acceptance of this second hypothesis is the fact that a suitable structural pattern, known to be unrelated to differences in original shell composition and yet to have been produced by structures known on brachiopod shells, has not been found on specimens of *Acanthospirina aciculifera* (Rowley) Schuchert and LeVene or on closely related forms. Small hollow oblique spines that did not penetrate the innermost shell layer and were arranged in a manner similar to the arrangement of the markings, or very oblique ectopunctae which penetrated some of the inner shell layers and were arranged in a like manner, would provide a satisfactory pattern. Punctae described from very closely related genera are, however, endopunctae and hence penetrate the innermost shell layer as well as other inner layers. Furthermore, they are more or less normal to the shell surface. They would therefore not provide a suitable structural pattern. Some spiriferoid genera have been said to have ectopunctae but they probably do not penetrate inner shell layers (4, p. 420). Other spiriferoid genera have oblique spines which might possibly form excavations if partly removed by weathering or abrasion. If these spines were oblique enough, had their proximal ends buried in the shell substance for some distance, and were arranged in alternate radial rows, they would provide a suitable pattern. No such spines, however, are known on *Acanthospirina* and because spines of larger size and of a different character are known, it is unlikely that they will be found. Besides being relatively large, the spines on *Acanthospirina aciculifera* (Rowley) Schuchert and LeVene are mounted on tubercles and set at right angles to the shell surface. Broken ends of these spines are irregularly distributed over the surface of the color-marked specimens, but they should not be confused with fine, hollow, regularly arranged oblique spines which would be necessary to form a pattern like that here described. The apparent absence of such a pattern can reasonably be interpreted as favoring the hypothesis that the coloration is original.

The strongest support for the first hypothesis, that the coloration is original, comes from the occurrence together, and in combination, of so many relations that have been observed on recent color-marked forms, or have been described from fossils that have markings rather generally thought to be original. Agreement with most recent color markings is shown in the following particulars: (1) The markings are arranged in a definite pattern which occurs on more than one individual. The comparison is here made with recent forms having definite markings and not with those recent forms that are merely shaded. (2) The markings or excavations, which under this hypothesis are assumed to result from them, occur on all parts of the surfaces of the valves like they do on most recent color-marked shells, and hence are not accidental. Some recent marine shells have markings only on the side nearest the surface, but even on these individuals the markings are regularly distributed on that side. The markings on the writers' specimens appear to be unrelated to life habits. (3) Although the pattern caused by the arrangement of the markings does not closely resemble any color pattern known on recent brachiopods, it does resemble a color pattern that occurs on living gastropods. Such a pattern was seen by the junior author on two immature individuals of a gastropod collected by him on the beach near Beaufort, N. C., and identified by Dr. W. P. Woodring, of the U. S. Geological Survey, as *Crepidula fornicata* (Linné). The pattern on the gastropods consisted of red streaks which were relatively much larger than the markings on the fossil brachiopods. The shortest streaks, which were near the margins of the gastropod shells, formed that part of the pattern which was most like the one here described. (4) Most of the coloring material is in grooves beneath the shell surface, which suggests that, like the coloring material in recent shells, it was situated in the inner shell layers. (3, p. 281; 5, p. 145.) (5) The coloring material appears to be absent from the innermost shell layers, likewise as in most recent shells. (5, p. 145.) (6) The present color of the markings is perhaps not significant, but it is, nevertheless, a color that is commonly seen on recent color-marked shells. (7) Although the chemical composition of the material does not correspond exactly with that of organic pigments, the presence of iron in it and the discovery (6, p. 92) that iron occurs in pigments of recent molluscan shells may have some significance. (8) Similarity of the markings to recent color markings is also shown by the observation of Doctor Ross that the microscopic particles of coloring matter in the markings of the Louisiana limestone specimens are intermingled with shelly particles, or embedded as discrete particles in the shell substance—a relation noted in recent shells by the writers.

Agreement with markings thought to be original on fossil brachiopods is shown in some details of the color and composition of the markings, in the relation of coloring matter to shell substance, and, in a more general way, in the plan of the pattern. Although the pattern is not exactly like any original pattern on fossils, its radial plan and broad resemblance to them is suggestive. The color patterns on most fossil brachiopod shells consist of bands, long radial lines, or rather large splotches of color whereas the pattern here described consists of short streaks and spots of color of very small size. These differences in size and in the continuity of the streaks are, however, less important than the likenesses shown by its general plan. The coloring matter in most fossil shells occurs in the inner shell layer, as noted by Richter (6, p. 89), Foerste (5, p. 145), and others, and the location of most of the coloring matter in grooves beneath the shell surface on the specimens of *Acanthospirina aciculifera* (Rowley) Schuchert and LeVene suggests that it also occurs in an inner shell layer. Furthermore, its absence from the innermost layer suggests another similarity in position to described fossil markings. The raised position of some of the markings and absence of coloring material from some parts of the pattern are also common features that have been explained by differential weathering of fossil color patterns (2, p. 212; 3, p. 281; 5, p. 145). The color of the markings, though perhaps of a slightly different shade from that of most fossil markings, is nevertheless a rather common one. The colors most commonly recorded on fossil specimens are brown or black, but reddish-brown and purple markings are not uncommon. Reddish-brown, olive-brown, and purplish spots were observed by C. L. and M. A. Fenton (7, pp. 132–133) on two species of *Cranaena* from Devonian of Iowa; reddish-brown spots occur on individuals of *Pugnax pugnus* (Martin) Hall and Clarke (8, p. 257), and reddish-brown to black concentric lines occur on *Rensselandia cimex* (Richter) Schuchert and LeVene (6, p. 88). The composition of the markings on the Louisiana limestone specimens could not be determined satisfactorily, nor is it known for many markings on fossils, but the presence of iron in the markings suggests a similarity with the composition of other fossil markings. Iron was discovered in the coloring materials of patterns in fossil shells as early as 1871 by Kayser (8, p. 260), who analyzed the substance in the reddish-brown areas of *Pugnax pugnus* (Martin) Hall and Clarke. Richter (6, p. 92) later found traces of iron in colored areas of *Rensselandia cimex* (Richter) Schuchert and LeVene, a Devonian brachiopod, and it has been found in the coloring material of other fossils (1, p. 84; 9, p. 391).

Despite the fact that the agreement in so many particulars of the markings with recent markings or with the criteria used to establish color markings in fossils appears to make the hypothesis of original coloration the most plausible one, it must be conceded that this agreement does not furnish conclusive evidence because the criteria used are themselves inconclusive. Each character and relation of the markings can be explained as a product of secondary infiltration about as well as it can be explained as a product of original coloration. The regularity of the pattern, its occurrence on more than one individual, and its distribution over all parts of the surfaces of each individual can be explained by the second hypothesis by assuming that the pattern existed during life as a structural pattern devoid of coloration. The location of the coloring matter in grooves beneath the shell surface, and its absence from the innermost shell layer, might be attributed to its infiltration into oblique spines or punctae which penetrated some of the shell layers, but did not penetrate the innermost layer, or to the filling of endopunctae which may have penetrated all the inner shell layers. These endopunctae could have been exposed at the shell surface after death by weathering of the outer shell layer and they could have then been partly plugged up before the coloring material was introduced. The raised position and extension of the ends of a few of the markings above the shell surface could also be explained by the hypothesis of secondary infiltration by assuming that the pigment filled hollow spines, or that the shell weathered away more rapidly than the filled punctae. Likenesses in color and—to a certain degree—in composition might be accidental and not particularly significant because red iron-bearing compounds of secondary origin are common on the associated specimens. Furthermore, the value of the close commingling of particles of shelly material and of coloring material as evidence for original coloration is questionable, for it is true that red iron oxides of secondary origin are known to occur in exactly the same manner.

A careful consideration of the points brought out in the above discussion demonstrates at least to the writers' satisfaction that no choice between hypothesis one and two can be confidently made. From an examination of the literature one would conclude that a pattern like this would ordinarily be described as an original coloration, but the hypothesis of original coloration when tested critically is little, if any, stronger than the hypothesis of secondary infiltration.

If the hypothesis of original coloration is, however, the correct one, the individuals here described provide the first record of an *Acanthospirina* with color markings that are original and the second record of color markings in the Spiriferidae, and they also furnish a new type of original color pattern. If the coloration is the result of infiltration or replacement these specimens are worthy of record, not only because of their resemblance to color patterns that have been described from fossils as original, but also because of their striking and unique appearance. At all events, they serve to draw attention to the difficulty of determining definitely whether color patterns on Paleozoic fossils are of primary or secondary origin.

NEW RELATIONSHIPS SHOWN BY THE COLORED INDIVIDUALS

Quite aside from their interest as color-marked individuals, these specimens are significant because of the new facts they show that bear on the relations of *Acanthospirina*. The species under consideration was originally described by the senior author of this paper as *Spirifer aciculifera*. Weller later chose it for the type species of his genus *Acanthospira*. Schuchert and LeVene (10, p. 119) discovered that *Acanthospira* was a homonym and proposed the generic name *Acanthospirina* to replace it. The essential generic character cited by Weller is the presence of fine spines on the surface, which, he stated (4, p. 418), were arranged in regularly radiating series along the summits of the plications and in similar rows on the fold and sinus. This distinctive character of *Acanthospirina* was inferred from the presence of minute tubercles or papillae, which Weller thought "doubtless supported slender spines in the living shell." (4, p. 419) Weller evidently found no such fine spines in place, but it may now be definitely said that they existed, for one result of the writers' study of these specimens was the identification of three such spines which had been broken off from the summits of the tubercles but were still sufficiently close to enable one to see that they were formerly mounted on the tubercles and projected approximately at right angles to the shell surface. The tubercles themselves, however, are easily seen. That they are neither as nearly equal in number on the two valves nor as regularly arranged as Weller's description would indicate is apparent in Figures 1 to 4. One individual has a considerable number of tubercles on the brachial valve and none on the pedicle valve. The other individual has few tubercles and these are widely and irregularly spaced.

In preparing his generic description Weller did not describe the pattern that forms the subject of this paper, though even where not emphasized by coloration it is visible under moderate magnification on all three specimens recently examined by the writers, including the holotype. Weller (4, p. 390) did, however, describe such a pattern, which incidentally was not shown in color, on *Syringothyris hannibalensis* (Swallow) Hall and Clarke from the same horizon and probably from the same locality. The presence of this pattern on *Syringothyris* suggests an affinity of *Acanthospirina* with *Syringothyris*. This affinity is further indicated by the preservation on one specimen of *Acanthospirina* of a delthyrial plate which bears a median ridge similar to those made by the posterior side of the syrinx on *Syringothyris*. Whether or not this specimen, or any of the other three specimens known to the writers, has a syrinx can not be determined except by sectioning, a course which has not been pursued because of the small number of specimens, only two of which belong to the same collection. In view of these resemblances, however, it appears very probable that when further investigation is possible it will be found that *Acanthospirina* resembles young specimens of *Syringothyris* in every character except in the possession of the fine spines mounted on tubercles.

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BOTANY.—Thelebolus lignicola *and the genus* Pleurocolla (*Fungi*).[1]

William W. Diehl, Bureau of Plant Industry. (Communicated by J. A. Stevenson.)

Under the name of *Thelebolus lignicola*, C. G. Lloyd[2] discussed and illustrated by three excellent photographs a specimen from New York gathered by S. H. Burnham in 1917. The description is, however, considerably at variance with the evidence obtained from a study of the Burnham specimen in the Lloyd Herbarium as No. 28,444, together with comparisons of other specimens, some in a living condition in moist chamber culture. Examinations of living and preserved material explain in part Lloyd's suppositions and reveal the taxonomic relations of the fungus.

The specimens do not show the presence of ascospores as suggested by Lloyd but of numerous acrogenous conidia upon verticillately branched conidiophores (Fig. 1) massed with paraphysis-like sterile hyphae of irregular length in sporodochia of variable form. The sporodochia when moist are mucose to gelatinous but corneous when dry. When young, they are verrucoid-pulvinate. With increase of size they assume various shapes, subpulvinate to irregularly-columnar, sometimes branched, but in general apically globular to pointed. By virtue of a more rapid growth under conditions of suitable moisture and drying, this apical region of the sporodochium is often, but not always, thrust upward as a subspherical, secondary development or proliferation which extruding readily becomes separated, suggesting a peridiole. It was this peridiole-like feature which prompted Lloyd's reference of the fungus to *Thelebolus*.

[1] Received September 5, 1932.

[2] Mycological Notes, no. 51, pp. 737–738, 1917.